

The cyclone considered is an ideal one, with circular isobars so spaced that the pressure distribution is amenable to mathematical expression and yet similar to what is often observed in real cyclones, superposed upon, and moving with uniform speed in a straight line through, a region of straight, parallel, equidistant isobars resulting from a distribution of temperature decreasing uniformly upward and northward in accordance again, roughly, with what is often observed. The latter pressure system, called the "stationary system," results in a geostrophic wind increasing upward, from zero at the surface, to great velocities at the cirrus level.

The fundamental differential equations of motion, which include the effects of turbulence and ground resistance, to which this scheme leads, can not be integrated; and the author develops a graphical method of solution, by which synchronous representations of air trajectories relative to the ground, trajectories relative to the moving center of the cyclone, and wind velocities relative to the ground, may be constructed for any level. From these, the regions of rising and falling air may be found also. The supply of energy necessary for the maintenance of a travelling wind system is assumed to come from the kinetic energy of the upper layers of the current produced by the stationary pressure system.

The cyclone, on this theory, may be divided into four principal or representative strata:

(1) The Ground Stratum, in which there is little or no wind arising from the stationary system; in this stratum, the actual wind velocities as depicted on a synoptic chart give the impression that the air is streaming from every side toward the center, but in reality the air streams into the cyclone only at the front; most of it leaves at the rear, but a minor part is drawn toward the center and must there ascend. Over most of the interior of the cyclone, air is rising; and in the outer parts and outside the cyclone proper, air is falling.

(2) The Lower Stratum of the free atmosphere, comprising that region in which the velocity of the wind due to the stationary system is *less* than the speed of the cyclone; in this stratum, a considerable part of the air spirals very slowly toward the center.

(3) The Central Part of the cyclone, in which the wind due to the stationary system has the *same* velocity as the speed of travel of the cyclone. Relative to the moving center, the air moves round and round this center in concentric circles. No addition to ascending or descending air is contributed by this stratum.

(4) The Higher Stratum of the free atmosphere, in which the wind due to the stationary system *exceeds* in velocity the speed of the cyclone; the air which is thrust up in the lower levels of the cyclone can not escape until it reaches this highest stratum, where it is carried forward out of the system. The descending air is similarly sucked from the highest stratum to the ground. The author considers that in most cases the decay of an Atlantic storm is due to the dying out or disturbance of the stationary pressure field.

An inversion of temperature will occur in the free air only where air is warmed up when contracted during descent, and, since this air is coming from the upper layers, it will be dry. However, a discontinuity of temperature, or "cold front" will be formed in the lowest level, at the place where observation shows the squall-line to exist; but the surfaces of discontinuity will vanish in the free air: The polar front is thus a consequence of the manner in which the air motions take place, and is not, as in Bjerknes' theories, the cause of the cyclone.

The theory is claimed to provide a foundation for an adequate explanation of extratropical cyclones; and the author is satisfied that it is in reasonable accord with observed facts. A number of facts which are explained by the theory are pointed out; and a critical examination of the foundations and postulates of the theory leaves a favorable impression. Of course, a *complete* theory must take into account many factors necessarily neglected in this study.

The kinematical problem with which Ryd has concerned himself is quite similar to the one recently investigated by Kobayasi, and the conclusions of the two are substantially in agreement.³

ON THE MECHANISM OF CYCLONES AND ANTI-CYCLONES.

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By T. KOBAYASI.

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Contrary to the Bjerknes conception of the function of the polar front as a causative factor in the formation of cyclones and anticyclones, the author begins by regarding the cyclone as a circular phenomenon. This suggestion arises from the widely observed fact that not all cyclones have a well-defined polar front, especially those that are slow moving.

Therefore, regarding the cyclone kinematically, the author deduces mathematically the equations of air trajectories over the earth's surface. To accomplish this, certain assumptions are necessary: (1) In the central region of a cyclone, called by the author the "principal part," there is not great variation of wind speed with increase of distance from the center; (2) outside the "principal part" the air is moving horizontally; (3) in the "principal part," at the surface, the wind is moving relative to the center approximately three times as fast as the center is advancing, and at an angle of 20° to the isobars. The resultant air trajectories thus theoretically obtained agree fairly well with those found by Shaw and Lempfert in their study of the "Life history of surface air currents." In the treatment of more complicated conditions the determination of theoretical air trajectories must be graphical but the results will not differ much from those found in this study, providing it is always assumed that within the storm the air is moving faster than the velocity of translation of the center and that at a distance from the center the air is moving slower than the velocity of translation.

The important feature thus revealed is that, along a line extending from the center of the cyclone toward the southwest there will occur a sharp discontinuity of temperature *if there is a steep horizontal gradient of temperature normal to the direction of translation of the cyclone*. If there is no such temperature gradient in the field of the storm's activity, this thermal discontinuity will not appear. This line corresponds to the well-known Bjerknes "cold front." The author maintains, it is seen, that the thermal discontinuity is a *result* and not a *cause* of the cyclone.

The angle between the actual wind and the gradient decreases with increase of altitude, and the ratio of wind velocity to velocity of translation of the pressure system also increases. At a certain height, assumed by the author to be 1,000 meters, the angle becomes 0° and this

³ See this REVIEW, pp. 37-38.

ratio about 5.3. The result of this decrease of angle and increase of ratio is that the line of discontinuity in the free-air overruns that at the surface, producing instability, if there be great contrast of temperature, the heavier air from above descending to the surface and causing the cold front to advance faster than the storm center.

Another line of importance comes from the mathematical treatment, and that is called by the author "the boundary of the centripetal current," a curve which approaches the storm center from the southeast, crosses the cold front at a point south of, and where no motion exists relative to, the storm center, passes around the storm center to the north, and finally off again to the southeast approximately parallel to, but some distance north of, its incoming branch. Within the area determined by this line, all the air reaches the storm center and ascends; outside the line, the air moves so as to flow away to the rear of the cyclone (relative to the storm center). The width of this belt of inflowing air is at a maximum about 150 meters above the ground, and it disappears at the level where the actual wind agrees in direction with the gradient wind. The conclusion is that the storm thus removes the air within this narrow belt extending toward the southeast, and brings the air on either side of it in contact, thus making such difference of temperature as may exist manifest itself most strongly along the cold front, or squall line.

As to the steering line, or warm front, the author is not prepared to offer an explanation, but the fact that it does not always occur causes him to suggest that this line is not essential to the cyclone, but that it is a thermal discontinuity left behind by a preceding cyclone and adopted by the storm in question. This would preclude the first storm in the Bjerknesian "family" ever having a warm front.

Slight attention is given the anticyclone owing to the difficulties of making appropriate assumptions. He shows that temperature discontinuities may be produced by an anticyclone, but the temperature differences will be usually very small.—C. L. M.

THE TWO-AND-A-HALF YEAR CYCLE IN WEATHER AND SOLAR PHENOMENA.

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H. W. CLOUGH, Meteorologist.

[Author's Abstract.]

During the last 25 years a number of writers have called attention to a short cycle in weather elements, and estimates of its mean length have varied from 2.5 to 3.7 years. Bigelow (1894) was probably the first to mention this cycle which he regarded as one-fourth of the sunspot cycle, or $2\frac{1}{4}$ years, but subsequently referred to it as a 3-year cycle. Later investigators include Lockyer (1902-1908), Arctowski (1909), Braak (1910), Wallén (1910), Johannsson (1912), Krogness (1917), and Helland-Hansen and Nansen (1917). Those who regarded the length of the cycle as 3 to 3.7 years employed annual means, thus obscuring some short fluctuations of small amplitude, while those who made the length 2.5 to 3 years, as Arctowski, Wallén and Helland-Hansen and Nansen employed consecutive 12-month means.

In the present investigation the author has employed the two 12-month means centering January 1 and July 1,

the latter being the ordinary calendar-year mean. The annual variation is eliminated, while the large departures of the colder months are grouped together in the January 1 mean. A plot of these two yearly means satisfactorily exhibits the short cycle, although in some cases the existence of a maximum or minimum phase is indicated only by an inflexion in a continuous ascent or descent of the curve, due to a longer variation. The amplitude of the short cycle is, generally, however, sufficiently large in comparison with that of the variations of longer period, as the 7 or 11 or 35 year cycles, so that the determination of the maximum and minimum phases is, as a rule, quite unaffected by the existence of the longer cycles.

The object of the investigation has been to determine, to the nearest quarter-year the maximum and minimum phases of the cycle as far back as temperature records are available—1770 in the United States and 1730 in Europe. Pressure records from 1740 in Europe have also been examined and serve to confirm the epochs derived from the temperature curves. Rainfall curves exhibit the cycle with much less regularity than temperature and pressure. Contemporaneous curves for several stations have been examined during the entire period of time for mutual confirmation and elimination of instrumental errors, change of exposure, or location and the small differences normally occurring between localities more or less distant from each other. The United States records from 1770 to 1923 yield a mean interval of 2.30 years between successive maxima and minima of the cycle. The mean deviation of the intervals from this mean is 0.35 year, while the mean variability is 0.34 year. The latter measure of dispersion being even smaller than the mean deviation, while normally it should be $1.4 (\sqrt{2})$ times greater, indicates the existence of marked secular variations in the length of the cycle. A plot of the phase intervals from 1770 shows a highly irregular variation about the mean interval, 2.30, ranging from 2 years or less about 1775, 1815, 1850, 1880, and 1910, or the epochs of maximum rainfall in the Brückner cycle, to $2\frac{1}{4}$ or more years at the intermediate dates. There is also a marked tendency to a shortening of the cycle within a few years after each sunspot maximum in the 11-year cycle. The range of this 11-year variation is about one-half that of the 35-year variation. The mean duration of the cycle from European data beginning 1728 is 2.20 years. This lower average is due to the low average, 2 years, of the period 1728-1770. There is furthermore apparent from the plot a progressive increase in the length of the cycle from the middle of the eighteenth century to the present time, which is, in all probability, due to a long cycle of about 300 years. A point to be emphasized is that the cycle changes in length gradually, not abruptly. The epochs of high and low temperature in Europe and the United States, east of the Rocky Mountains, are, on the average, practically coincident, Europe averaging 0.06 year later. The individual differences from true coincidence average about six months, and 85 per cent of these differences are between ± 0.75 year.

From inspection of the curves of temperature it is apparent that the amplitude at the above-mentioned epochs of maximum rainfall in the Brückner cycle is perhaps only one-half the amplitude at the opposite epochs, 1800, 1830, 1865, 1890, and 1925. At Portland, Oreg., the length of the variation was about 2.20 years and the mean amplitude 1.5° in 1880 and 1910, while in 1890 and 1920 the values were 3 years and 3° , re-

¹The complete article, of which this is an abstract, will appear in a later number of the Review.